(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 732 743 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
18.09.1996 Bulletin 1996/38

(51) Int Cl.6: **H01L 23/427**, H01L 23/373

(21) Application number: 96301801.5

(22) Date of filing: 15.03.1996

(84) Designated Contracting States:
DE FR GB IT NL

(30) Priority: 17.03.1995 US 406226

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(54) Heat sinks

(57) A heat sink which comprises an enclosure having a highly thermally conductive surface region (3) and defining an enclosed cavity. A porous, highly thermally conductive material (1) is disposed in the cavity, preferably homogoneously therein, and is thermally coupled to the thermally conductive surface. A phase change material (7) changing from its initial phase, generally solid, to its final phase, generally liquid, responsive to the absorption of heat is disposed in the enclosed cavity and in the porous material. In accordance with a first embodiment, the highly thermally conductive surface region (3) is preferably aluminum and the porous medium (1) is a highly thermally conductive porous medium, preferably aluminum. In accordance with a second embodiment, the thermally conductive surface is composed of highly thermally conductive fibers (13) disposed in a matrix and the porous material is a plurality of the thermally conductive fibers extending from the thermally conductive surface into the cavity. The highly thermally conductive fibers are preferably graphite and the matrix is preferably an epoxy.

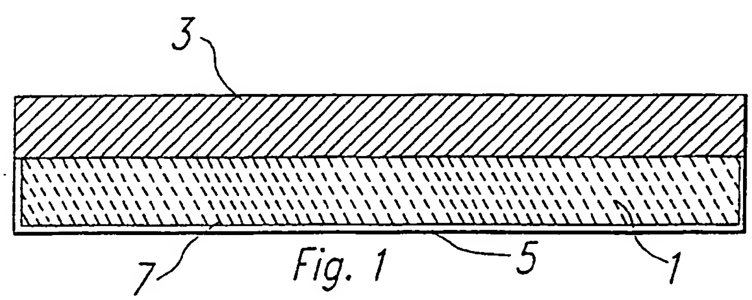

Fig. 1

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Printed by Jouve, 75001 PARIS (FR)

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Description

This invention relates to heat sinks and, more specifically, to heat sinks wherein heat is absorbed by the phase change of a phase change material.

BRIEF DESCRIPTION OF THE PRIOR ART

For certain applications, electronic circuit board and component heat sinks are built with embedded phase change material (PCM). Phase change materials for such purposes are well known in the art, an example thereof being a wax which preferably has a unitary melting temperature, paraffins of this type being readily available and well known. The PCM absorbs waste heat as it changes from the solid state to the liquid state. PCMs are also available which can further change from the liquid state to the gaseous state or merely operate in the latter two phase states. Currently, heat sinks which use a PCM are built in several ways. One way is to machine thermally conductive fins in a thermally conductive plate, such as, for example, aluminum or copper. PCM is poured into a cavity containing the fins and a lid is used to seal the PCM volume. Heat is drawn to the fins and then from the fins into the PCM with the PCM changing phase as it absorbs the heat. An alternate means of construction is to build a similar assembly using commercially available thermally conductive fin stock. In this alternate configuration, the fin stock is vacuum brazed or dip brazed to a thermally conductive plate.

In both cases, the thermal efficiency of the system is limited by the minimum obtainable feature sizes of machined fins and fin stock since the amount of heat transferred from the fins to the PCM is related to the amount of fin surface contacting the PCM as well as the amount of PCM material available for phase change. The goal is to have the minimum fin thickness and the minimum distance between fins while having the maximum possible volume of PCM in the cavity area. Maximum PCM volume is obtained by having the minimum fin thickness. The minimum distance between fins is required to reduce the thermal resistance between the fin and the PCM melt front. With either machined fins or fin stock, heat from localized sources is transferred directly into the PCM under the heat source and along the fin length to the PCM not located directly under the heat source. Fins essentially provide two dimensional heat flow. This limits the thermal performance of the heat sink.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a heat sink having three dimensional properties and capable of providing improved thermal performance relative to the above described prior art systems.

Briefly, there is provided a highly thermally conductive porous medium to replace the machined fins and fin stock, the porous medium preferably filling the volume containing the PCM. Since porous media have randomly aligned stringers that are all interconnected, the transfer of heat is three dimensional. This improves the transport of heat from localized sources. In addition, the porous medium stringers are very small and surround small pockets of PCM. This feature minimizes the thermal resistance between the heat sink and PCM melt front. Accordingly, the present invention provides a highly thermally conductive porous medium which has a higher percentage of surface area per unit volume available for contact with the PCM than in the prior art and which preferably fills the PCM-containing volume, preferably on a somewhat homogenous basis and as homogeneous a basis as can be provided with a porous medium, as well as filling this volume. The prior art fins do not provide the degree of homogeneity available with the use of the porous media in accordance with the present invention.

Homogeneity provides a more efficient PCM heat sink with greater temperature uniformity.

A heat sink in accordance with a first embodiment of the present invention includes a highly thermally conductive porous medium, preferably an aluminum foam of the type sold under the trademark "Duocel" by ERG Materials Division, 900 Stanford Avenue, Oakland, California. The porous medium is secured to a highly thermally conductive plate, such as, for example, aluminum, by, for example, vacuum brazing to the plate. The plate is a heat sink mounting surface with a cover or lid and, with the lid, forms a cavity capable of retaining the porous medium therein as well as the PCM in both the solid and liquid state to enclose the porous medium and PCM within the cavity. Once the lid and plate are fabricated and assembled, the porous medium is placed in the cavity and the PCM is melted and poured into the voids of the porous medium as well as part and preferably all of the remainder of the cavity. This results in a PCM filled heat sink to which electronic components can be mounted. The lid is then placed over the plate to provide a sealed cavity within the heat sink containing the porous medium and the PCM material within the cavity. The heat sink can be a stand-alone piece or integrated as part of an electronic circuit board. An integrated approach employs the PCM-filled structure as the substrate upon which circuit layers are built. This basic type of circuit construction is currently in use in conjunction with prior art heat sinks as described hereinabove.

In accordance with a second embodiment of the invention, the plate of the first embodiment is made of a highly thermally conductive composite fiber material in a matrix, such as, for example, graphite fibers in a matrix of preferably an epoxy, such as for example AMOCO K1100X. Composite fibers without matrix extend from the plate, into the PCM cavity. These fibers are highly heat conductive and perform the same function as the machined fins and fin stock as discussed hereinabove. However, these fibers can also be arranged so that

some of the fibers extend out of the matrix and into the cavity to substantially fill the cavity while also being porous as in the case of the first embodiment. With fibers forming a mat of thermally conductive elements or stringers, the same improvements in thermal performance seen with porous foam media are also realized. Both porous foam media and fibrous media enhance the thermal performance of PCM embedded heat sinks. They can either be stand-alone heat sinks or be integrated with the electrical circuit substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a schematic diagram of a heat sink in accordance with a first embodiment of the invention using a porous unitary medium;
FIGURE 2 is a schematic diagram of a heat sink in accordance with a second embodiment of the invention using a fibrous plate with fibers from the fibrous plate extending into the PCM cavity to provide the equivalent of a porous medium in the cavity; and
FIGURE 3 is a cross-sectional view of a heat sink which can use the heat sinking material in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGURE 1, porous aluminum medium 1 is vacuum brazed to an aluminum plate 3, which is a heat sink mounting surface, with a cover or lid 5 forming a cavity with the aluminum plate 3 to enclose the porous aluminum medium in the cavity. Heat generators (not shown) are preferably secured to the outer surface of the plate 3 after heat sink fabrication. Once the components of the heat sink are fabricated and assembled, PCM 7 in the form of paraffin is melted and poured into the voids of the porous material 1 and also partially or fully fill the remainder of the cavity. This results in a PCM filled heat sink to which electronic components are mounted. The heat sink can be a stand-alone piece or integrated as part of the electronic circuit board. In an integrated approach, the PCM-filled structure is employed as the substrate upon which circuit layers are built.

Referring to FIGURE 2, the plate 11 is fabricated of a composite fiber material, preferably highly thermally conductive graphite in a matrix, preferably an epoxy. A preferred material for plate fabrication is AMOCO K1100X. In this design, composite fibers 13 from the plate 11 without matrix attached extend from the plate into the PCM cavity to provide good thermal contact between the fibers 13 and the plate 11. These fibers 13 are highly thermally conductive and perform the same function as the machined fins and fin stock of the prior art and the porous media of the first embodiment discussed hereinabove. The PCM material 15 is then entered into the cavity as in the first embodiment and the lid 17 and then closed to provide the enclosed cavity. With fibers 13 forming a porous mat of thermally conductive elements or stringers, the same improvements in thermal performance seen with porous media are also realized.

Both porous media and fibrous media enhance the thermal performance of PCM embedded heat sinks. The heat sinks can either be stand-alone heat sinks or be integrated with the electrical circuit substrate.

An example of a PCM substrate/module is shown in FIGURE 3. An enclosure is formed using a plate of aluminum 21 secured to a wall member 23 which can be of any material capable of withstanding the conditions to which the module will be subjected, such as a plastic. The porous medium 25 is placed in the cavity formed by the wall 23 and plate 21 and the PCM material 27 in liquid form is then poured into the cavity and the lid 29 is then secured to the wall 23 to enclose the porous medium and PCM material within the cavity. Components, circuit boards or other heat generators are then secured to the plate 21 for extraction of the heat therefrom and conduction of this heat to the PCM material 27 via the porous medium 25.

Though the invention has been described with respect to specific preferred embodiments thereof, many variations and modifications will immediately become apparent to those skilled in the art. It is therefore the intention that the appended claims be interpreted as broadly as possible in view of the prior art to include all such variations and modifications.

Claims

1. A heat sink which comprises:

an enclosure having a highly thermally conductive surface region and defining an enclosed cavity;
a porous, highly thermally conductive material disposed in said cavity and thermally coupled to said thermally conductive surface; and
a phase change material changing from its initial phase to its final phase responsive to the absorption of heat disposed in said enclosed cavity and in said porous material.

2. The heat sink of claim 1 wherein said initial phase of said phase change material is the solid phase and said final phase is the liquid phase.

3. The heat sink of claim 1 or claim 2 wherein said porous medium is a highly thermally conductive porous medium.

4. The heat sink of claim 3 wherein said porous medium is aluminum.

5. The heat sink of any preceding claim wherein said porous material is substantially homogeneously

disposed within said cavity.

6. The heat sink of any preceding claim wherein said thermally conductive surface is composed of highly thermally conductive fibers disposed in a matrix and wherein said porous material is a plurality of said thermally conductive fibers extending from said thermally conductive surface into said cavity.

7. The heat sink of claim 6 wherein said thermally conductive fibers are graphite.

8. An electronic circuit board including a heat sink as claimed in any preceding claim.

9. Electronic apparatus including a heat sink as claimed in any of claims 1 to 7 or a circuit board as claimed in claim 8.

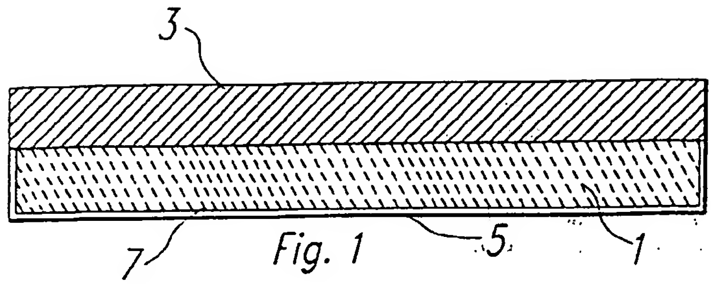

Fig. 1

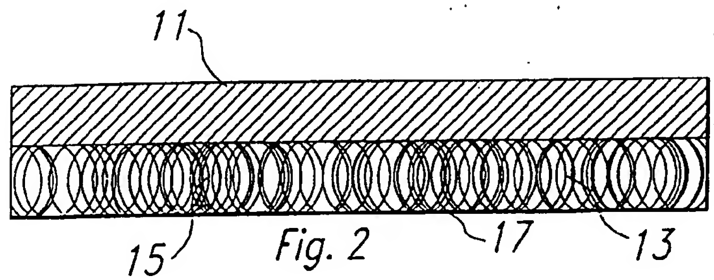

Fig. 2

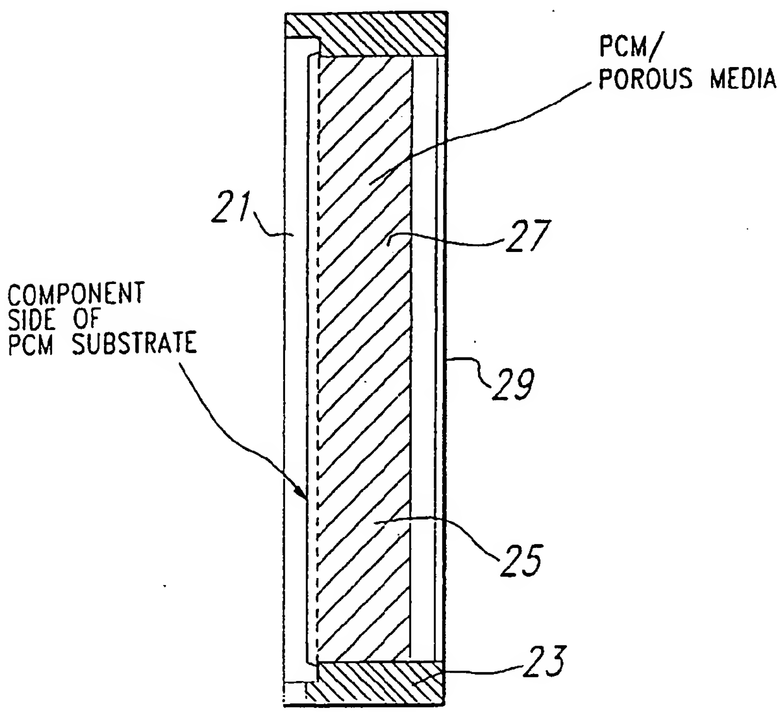

Fig. 3

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(11) EP 0 732 743 A3

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(88) Date of publication A3:
13.05.1998 Bulletin 1998/20

(43) Date of publication A2:
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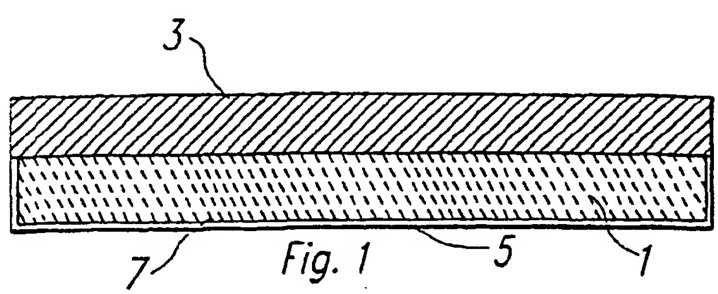

Fig. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 96 30 1801

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	"MELTING WAX COOLS HOT COMPONENTS" 10 October 1985 , MACHINE DESIGN, VOL. 57, NR. 23, PAGE(S) 48 XP000579938 * the whole document *	1-3,5,8,9	H01L23/427 H01L23/373
X	PATENT ABSTRACTS OF JAPAN vol. 013, no. 065 (M-797), 14 February 1989 -& JP 63 267890 A (TORAY IND INC), 4 November 1988, * abstract *	1,3,5	
X	US 5 325 913 A (ALTOZ FRANK E) * column 3, line 23 - line 67; figure 1 *	1,3,8,9	
X	US 4 966 226 A (HAMBURGEN WILLIAM R) * column 1, line 31 - line 60; figure 2 * * column 2, line 48 - column 4, line 41; figure 2 *	1,3,4,6-8	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
X	EP 0 541 456 A (TRANSCAL) * page 3, column 3, line 18 - line 34; claims 1,6; figure 1 * * page 3, column 4, line 31 - line 45 *	1,3-5,8,9	H01L
X	US 4 047 198 A (SEKHON KALWANT S ET AL) * column 4, line 66 - column 5, line 44; claims 1,2,5,6; figures 1-3 *	1,6-9	
X	PATENT ABSTRACTS OF JAPAN vol. 016, no. 230 (E-1208), 27 May 1992 -& JP 04 044352 A (FUJIKURA LTD;OTHERS: 01), 14 February 1992, * abstract *	1,8,9	

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 March 1998	Zeisler, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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X	PATENT ABSTRACTS OF JAPAN vol. 095, no. 001, 28 February 1995 -& JP 06 291480 A (MITSUBISHI ELECTRIC CORP), 18 October 1994, * the whole document *	1,8,9	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)

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